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Title

Design and validation of a three-instrument toolkit for the assessment of competence in ECG rhythm recognition.

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Abstract

Background: Rapid and accurate interpretation of cardiac arrhythmias by nurses has been linked with safe practice and positive patient outcomes. Although training in electrocardiogram (ECG) rhythm recognition is part of most undergraduate nursing programmes, research continues to suggest that nurses and nursing students lack competence in recognising cardiac rhythms. In order to promote patient safety, nursing educators must develop valid and reliable assessment tools that allow the rigorous assessment of this competence before nursing students are allowed to practise without supervision.

Aim: To develop and psychometrically evaluate a toolkit to holistically assess competence in ECG rhythm recognition.

Methods: Following a convenience sampling technique, 293 nursing students from a nursing faculty in a Spanish university were recruited for the study. The following three instruments were developed and psychometrically tested: a knowledge assessment tool (ECG-KAT), a skills assessment tool (ECG-SAT) and a self-efficacy assessment tool (ECG-SES). Reliability and validity (content, criterion and construct) of these tools were meticulously examined.

Results: A high Cronbach's alpha coefficient demonstrated the excellent reliability of the instruments (ECG-KAT=0.89; ECG-SAT=0.93; ECG-SES=0.98). An excellent context validity index (S-CVI/Ave>0.94) and very good criterion validity were evidenced for all the tools. Regarding construct validity, principal component analysis revealed that all items comprising the instruments contributed to measure knowledge, skills or self-efficacy in ECG rhythm recognition. Moreover, known-groups analysis showed the tools' ability to detect expected differences in competence between groups with different training experiences.

Conclusion: The three-instrument toolkit developed showed excellent psychometric properties for measuring competence in ECG rhythm recognition.

Keywords

Competence assessment; nursing students; self-efficacy; knowledge; skills; cardiac arrhythmias.

Introduction

Rapid and accurate interpretation of cardiac arrhythmias by nurses has been linked with safe practice and positive patient outcomes.[1-4] Conversely, it has been highlighted that errors in the recognition of life-threatening cardiac rhythms could compromise patient outcomes.[2-3] Consequently, regardless of their expertise, nurses are expected to be competent in electrocardiogram (ECG) rhythm recognition.[1-2,5-7] Nonetheless, this is not always the case and research suggests that qualified nurses often lack competence in ECG rhythm recognition.[8-11]

In many countries, nursing education does not include a final licensing exam, which means that nurses are allowed to practise without supervision immediately after completing their undergraduate programmes.[12] Therefore, in order to promote patient safety and positive patient outcomes,[1-4] most undergraduate programmes in nursing include training in ECG rhythm recognition.[13] In addition to this, our literature review shows that numerous efforts to design and implement innovative training interventions aiming to improve nursing students' acquisition and retention of competence in ECG rhythm recognition have been made.[14-18] However, the strategies used to evaluate the educational effects of the innovative interventions implemented in these studies were based on a traditional approach to competence assessment.[19-20]

This means that the assessment of nursing students' competence mainly focused on the partial evaluation of one or two of its domains (cognitive knowledge, performance or confidence),[19-20] which implies that nursing students' overall competence in ECG rhythm recognition remains unclear. Nursing educators are therefore challenged to find more comprehensive, reliable and valid strategies for the rigorous assessment of competence in ECG rhythm recognition.[21-24]

Developing and implementing an assessment approach based on Bloom's and Bandura's theoretical underpinnings could help to effectively address this challenge.[25-26] The adoption of Bloom's conception of competence as the individual's capacity to integrate knowledge, skills and attitudes to make the most appropriate decisions to achieve certain outcomes, may help improve the quality of assessments.[3,20,22,25] Furthermore, and following Bandura's theory, it is argued that the acquisition of knowledge and skills does not entail competence unless individuals also achieve a confident attitude in their ability to perform well.[24,26-28] Therefore, being competent in ECG rhythm recognition is understood here as having sound cognitive knowledge of the theoretical underpinnings of ECG rhythm interpretation, having the practical ability to recognise and name a cardiac rhythm recorded by an ECG, and acquiring a certain level of self-efficacy towards one's own capability to effectively perform the tasks involved in the process. Following our literature review, a lack of valid and reliable instruments to assess all these domains of the competence was found, so the aim of this study is to develop and psychometrically evaluate a toolkit to holistically assess nursing students' competence in ECG rhythm recognition.

Methods

Study design and participants

The present study used an observational cross-sectional design. Students from one Faculty of Nursing in Spain were recruited using a convenience sampling technique. The inclusion criteria for participation were: 1) enrolled in a Nursing degree programme during the 2015/2016 academic year, and 2) had not attended a training session in ECG more than 3 months before the data collection. A total population of 320 Spanish-speaking individuals met these criteria and 293 voluntarily participated in the study. Information about their age, gender and completed education was also collected. In order to allow later known-groups comparisons, the 293 participants were divided based on their last attended training in ECG rhythm recognition: 1) never attended training (year-1 students), 2) attended training immediately before completing the assessment (year-2 students), and 3) attended training between 1-3 months before the assessment (year-3 students).

Ethical considerations

After the Institutional Ethics Committee granted ethical approval, a member of the research team who was not part of the student Faculty contacted all individuals who met the criteria to participate in the study. This intended to avoid influencing their decision on whether or not to take part. A written document with information about the research design, its aim and the participants' rights was handed out to all the individuals who met the inclusion criteria. Volunteer participants were required to sign an informed consent document before enrolment. All data collected were treated in accordance with the European legislation on data protection.[29]

Initial development of the instruments

The toolkit for the holistic assessment of nursing students' competence in ECG rhythm recognition was comprised of three instruments developed and tested in

Spanish: a knowledge assessment tool, a skills assessment tool and a self-efficacy assessment tool.

A panel of 16 experts from 4 different institutions and a sample of 51 nursing students participated in the initial pilot test of the instruments. All the experts were experienced in either emergency, intensive or cardiac care and in teaching ECG interpretation skills for nursing students. The same inclusion criteria, sampling technique and ethical protocol used for the main sample were applied to the pilot sample. However, the 51 participants in the pilot test did not participate in the main validation study.

To assess content validity, the experts were asked to score each item as 1='not relevant', 2='somewhat relevant', 3='quite relevant' or 4='highly relevant' for measuring either knowledge, skills or self-efficacy in ECG rhythm recognition. Other authors' recommendations were followed to calculate the items' content validity index (I-CVI) for the initial version of the three assessment tools developed, and items with a I-CVI<0.70 were immediately discarded.[30-31]

To assess reliability and temporal stability, the pilot sample completed the questionnaires for knowledge, skills and self-efficacy assessment twice with a 4-week interval between them. While temporal stability of the tools was explored by calculating the Pearson's correlation coefficients (r) for the test-retest results, reliability was evaluated using the following three estimators for each individual instrument: 1) Cronbach's coefficient alpha for the whole tool, 2) the corrected item-total correlation (ITC) and 3) the estimated Cronbach's alpha of the tool if a particular item was removed. Items were retained as part of the tools if: 1) item's corrected ITC>0.3 and 2) the instrument's Cronbach's alpha coefficient did not increase after removing that particular item.

To assess readability and understandability, the experts and the students were asked to provide feedback on the wording of the items comprising the three tools and report any difficulties when reading them.

Details of the development process and pilot study of each tool are presented below.

The knowledge assessment tool

For the evaluation of the 'knowledge' domain of the competence, a multiple-choice questionnaire in ECG rhythm recognition (ECG-KAT) was created. The 20 questions comprising the initial version of the ECG-KAT (i-ECG-KAT) only had one correct answer out of four possible options [i.e. Question 4: what is the time equivalence in seconds of one of the big squares on the ECG paper? Answer options: a) 0.04s; b) 0.4s; c) 0.02s; d) 0.2s]. These questions assessed cognitive knowledge in the topics considered essential for the successful recognition of ECG rhythms: (1) anatomophysiological principles of the cardiac function, (2) basic concepts of ECG interpretation, (3) ECG's interpretation procedure, and (4) cardiac arrhythmias' characteristics.[17-18]

The I-CVI of the 20 questions comprising the i-ECG-KAT ranged from 0.75-1 so all of them were retained for its pilot study, after which this tool proved to be temporally stable ($r=0.73$) and reliable (all items' ITC>0.3; Cronbach's alpha=0.85, which would not have significantly increased if any of the items were removed). Moreover, experts' and students' feedback on the readability and understandability of the instrument was positive and only minor changes to the wording of 4 questions were applied.

The skills assessment tool

For the evaluation of the domain 'skills', a skill assessment tool in ECG rhythm recognition (ECG-SAT) was created. The initial version of the ECG-SAT (i-ECG-

SAT) was comprised of 10 ECG rhythm-strips that the students would have to individually interpret and name. In contrast to the skills tools found in the literature,[17,32] the i-ECG-SAT did not have an MCQ format. This means that the participants were not given possible answers with each rhythm-strip, decreasing their odds of getting the correct answer by chance and making the assessment more realistic.

The 10 ECG rhythm-strips comprising the i-ECG-SAT were retained as their I-CVI ranged from 0.87-1. After the pilot study, statistical analysis suggested that the i-ECG-SAT was temporally stable (r=0.79) and reliable (all items' ITC>0.3; Cronbach's alpha=0.89, which would not have significantly increased if any of the items were removed). Furthermore, experts and students provided only positive comments on the tool's completion instructions.

The self-efficacy assessment tool

Self-efficacy is defined as people's beliefs in their capabilities to perform a particular task and is considered to be the most important attitudinal component in the development of a competence.[26, 33] Therefore, to measure the 'attitude' domain of this competence, the self-efficacy scale in ECG rhythm recognition (ECG-SES) was developed. Following Bandura's recommendations for the development of self-efficacy questionnaires, the initial 15-item version of the ECG-SES (i-ECG-SES) measured participants' confidence in terms of 'can do' using a 0-100 response-scale.[26-28] Furthermore, in order to avoid ceiling effects on participants' self-efficacy scores, a certain level of difficulty was added to the statements included in each item.[26]

The I-CVI of the 15 items comprising the ECG-SES ranged from 0.75-1, meaning all of them were retained for its pilot study, after which statistical analysis suggested that the i-ECG-SES was temporally stable (r=0.81) and reliable (all items' ITC>0.4; Cronbach's alpha=0.93 that would not have significantly increased if any of the items were removed). Additionally, experts' and students' feedback on the readability and understandability of the tool was positive and only minor changes to the wording of 2 items were applied.

Lastly, the three instruments comprising the toolkit for the assessment of competence in ECG rhythm recognition followed the structure of ordinal scales. The ECG-KAT and ECG-SAT measured participants' knowledge and skills from 0-100. Each question in the ECG-KAT and rhythm-strip in the ECG-SAT was given a proportional and equal value. The ECG-SES measured participants' self-efficacy from 0-100 using a Likert-type scale in which 0 meant 'completely sure I cannot do at all' and 100 meant 'completely sure I can do'.

Data analysis of the instruments' final version

Following other authors' recommendations, the already-piloted version of the three instruments was psychometrically tested.[27-28,30-31,34-35] IBM® SPSS® version 21 for Mac® was used to perform the data analysis.

Readability and understandability. The readability and grade level of the ECG-KAT, ECG-SAT, and ECG-SES was analysed using the Flesch-Kincaid tool in Microsoft Word® 2011 for Mac®. To evaluate understandability, eight participants and three independent non-native Spanish-speakers were asked to provide comments on any difficulties found when reading the tools. Using non-native Spanish-speakers' feedback about the understandability of the tools can contribute to further simplify their readability.[27-28] The completion time of the three instruments was also recorded.

Reliability. The methodology used to measure the final-version tools' reliability was the same as the one already described in the 'initial development of the instruments' section.

Validity. Content validity of the final version of the ECG-KAT, ECG-SAT and ECG-SES was explored using the same method described in the section 'initial development of the instruments'. In addition to this, the scales' average content validity index (S-CVI/Ave) was calculated. In order to explore its criterion validity, participants' results on the three instruments comprising the toolkit were compared to other tools measuring similar constructs. Due to the lack of validated tools to which the ECG-KAT and the ECG-SAT could be compared for criterion validity, participants' results in both the ECG-KAT and ECG-SAT were correlated to their results on the assessment tool developed and used by Varvaroussis' et al.[17] Although less specific than the ECG-KAT and ECG-SAT, this tool had been previously used for the assessment of nursing students' knowledge-skills in cardiac arrhythmia recognition. Similarly, in order to determine the ECG-SES' criterion validity, participants' results in this tool were correlated to the New General Self-Efficacy Scale (NGSES), which measures individuals' general self-efficacy.[36] For the assessment of construct validity, the following two procedures were performed:

Principal Component Analysis (PCA). The Kaiser-Meyer-Olkin Measure of Sampling Adequacy and the Bartlett's Test of Sphericity preceded the process of exploring the factor structure of the ECG-KAT, ECG-SAT and ECG-SES. Then, an unlimited factor analysis test with Varimax rotation was run. Decisions on the on the correct structure of the three tools were made around the following criteria: (1) factors' eigenvalues ≥1, (2) existence of a clear graphic representation of the factor on the plot of eigenvalues, and (3) items' factor loading value ≥0.5.

Known-groups analysis. The total sample (*N*=293) was divided according to their last attendance of a training session in ECG rhythm recognition (either never trained (*n*=98), trained immediately before the assessment (*n*=91) or trained between 1-3 months before the assessment (*n*=104)). One-way analysis of variance (ANOVA) was used to analyse known-groups differences. Moreover, to evaluate the differences between groups' mean scores, Tukey's Honestly Significant Difference (HSD) post-hoc tests were performed.

Results

Description of the main sample

Table 1 presents detailed demographic information of the main study sample (*N*=293) and the known-groups. Female participants represented 80.5% of the total sample (*n*=236), of which the mean age was 21.19 years (SD=5.24; range=17-54). Furthermore, 76.8% (*n*=225) of participants had completed upper secondary education before enrolling in the undergraduate nursing degree and approximately 40% (*n*=114) of participants had cooperated in the interpretation of an ECG rhythm-strip. Lastly, one-way ANOVA results showed non-significant differences between the known-groups for any of the demographic characteristics studied (see Table 1).

Readability and understandability

The reading level of the ECG-KAT, ECG-SAT and ECG-SES corresponds to 12^{th}, 10^{th} and 12^{th} grade respectively. Neither the students nor the independent non-native Spanish-speakers reported any difficulties understanding the content of the three tools. Moreover, completion time register shows that participants took between 12-20 minutes for the ECG-KAT, 15 minutes for the ECG-SAT and 4-7 minutes for the ECG-SES. The mean completion time of the overall toolkit was just under 40 minutes.

Reliability

The results of the reliability analysis for the three instruments are shown in Table 2 (ECG-KAT), Table 3 (ECG-SAT) and Table 4 (ECG-SES). The Cronbach's alpha coefficient for these three tools was 0.89, 0.93 and 0.98 respectively. Furthermore, ITC ranged from 0.38-0.66 for the ECG-KAT, from 0.38-0.88 for the ECG-SAT and from 0.77-0.88 for the ECG-SES.

Validity

The I-CVI for the ECG-KAT, ECG-SAT and ECG-SES are presented in Table 2, Table 3 and Table 4 respectively. The panel of 16 experts reviewing the three tools considered that all items contributed to the operational definition of competence in ECG rhythm recognition as a measurable construct. In support of this, the items' I-CVI ranged from 0.75-1 and the tools' S-CVI/Ave were 0.94 (ECG-KAT), 0.97 (ECG-SAT) and 0.99 (ECG-SES). With regard to the criterion validity analysis, the ECG-KAT, ECG-SAT and ECG-SES showed high correlation with the tools they were compared to (r=0.61; p<0.01; r=0.67; p<0.01; r=0.70; p<0.01, respectively). Results for the construct validity evaluation are as follows:

PCA

The results for the Kaiser-Meyer-Olkin measure of sampling adequacy were: 0.898 for the ECG-KAT, 0.914 for the ECG-SAT and 0.946 for the ECG-SES. Moreover, the Barlett's Test of Sphericity was significant for all of them (χ^2=1224.87; p<0.01; χ^2=883.33; p<0.01; χ^2=5905.77; p<0.01), which means that it was appropriate to carry out PCA for the three instruments.

In the case of the ECG-SAT' and ECG-SES' structure, only one factor evidenced a clear graphic representation on the plot of eigenvalues and an eigenvalue$\geq$1. This factor accounted for 73% and 74.6% of the total variance found respectively. All the items of both tools were retained as their component loading values varied from 0.44-0.92 (ECG-SAT) and 0.80-0.90 (ECG-SES). On the contrary, the structure of the ECG-KAT proved to have the following four factors, which accounted for 51.44% of the total variance found: 1) anatomophysiological principles of the cardiac function, 2) fundamental concepts in ECG rhythm recognition, 3) interpretation procedure of ECG rhythms, and 4) cardiac arrhythmias' characteristics (see Table 5).

Known-groups analysis

One-way ANOVA evidenced significant differences in the mean scores between the three known-groups for the ECG-KAT ($F(2, 290) = 192.32$; $p<0.01$), ECG-SAT ($F(2, 290) = 240.55$; $p<0.01$) and ECG-SES ($F(2, 290) = 185.79$; $p<0.01$). Finally, Table 6 shows the results for the known-groups analysis and Tukey's HSD post-hoc tests.

Discussion

Our literature review suggests there is a lack of valid and reliable tools that allow the rigorous assessment of competence in ECG rhythm recognition amongst nursing students. In light of this argument, the present study aimed to develop and psychometrically evaluate a 3-instrument toolkit for the holistic assessment of competence in ECG rhythm recognition.

As part of the psychometric assessment process of the three instruments, reliability was carefully examined in order to determine whether they measured accurately. The final version of the ECG-KAT, the ECG-SAT and the ECG-SES proved to have an excellent internal consistency and a very good temporal stability, which evidences the high reliability, repeatability and reproducibility of the three tools.[34-35]

Furthermore, content, criterion and construct validity of all the instruments were meticulously tested in order to determine whether they actually measured what they intended to. Content validity of the three tools was evidenced after a panel of 16 experts considered that the 20 items comprising the ECG-KAT, the 10 items comprising the ECG-SAT and the 15 items comprising the ECG-SES were relevant for operationalizing the respective assessment of knowledge, skills and confidence in ECG rhythm recognition.[34-35] In relation to criterion validity, all the tools designed in this study correlated well with previously validated instruments measuring similar concepts. This could be interpreted as an indicator of the ECG-KAT's, ECG-SAT's and ECG-SES' ability to provide valid and reliable information about individuals' knowledge, skills or confidence in recognising ECG rhythms.[34-35] Additionally, regarding construct validity, PCA showed that whereas the ECG-SAT and the ECG-SES have a single-factor structure; the ECG-KAT has a 4-factor structure that corresponds to the topics other authors have recommended to consider when teaching how to recognise an ECG rhythm; these are: 1) anatomophysiological principles of the cardiac function, 2) fundamental concepts in ECG rhythm recognition, 3) interpretation procedure of ECG rhythms, and 4) cardiac arrhythmias' characteristics.[17-18] Moreover, corroborating the tools' construct validity, known-group analysis revealed that the ECG-KAT, ECG-SAT and ECG-SES were able to detect previously expected differences between individuals with different training experiences.[17,32]

Literature often suggests that nurses and nursing students' continue to lack competence in ECG rhythm recognition,[8-11] which could interfere with the achievement of positive patient outcomes.[1,4,14] Consequently, nursing educators are faced with the challenge of promoting safe practice by developing valid and reliable assessments tools that can be used to rigorously assess nursing students' competence before being allowed to work without supervision.[6,37]

It has been argued that accepting the holistic definition of competence could help nursing educators to develop more effective, valid and reliable assessment tools.[5,7,20,25] From this perspective, achieving a specific competence requires individuals not only to acquire and retain the knowledge and the skills needed to make the right decisions and correctly perform certain tasks, but also to adopt a confident attitude toward their own ability to do so.[25-28,33] Therefore, the development of the ECG-KAT, ECG-SAT and ECG-SES as three independent instruments comprising one comprehensive toolkit could contribute to the holistic and rigorous assessment of nursing students' competence in ECG rhythm recognition as well as to the understanding of their learning needs in this topic.

Although the evidence presented suggests that the toolkit developed for the assessment of competence in ECG rhythm recognition is comprised of three reliable and valid instruments, some limitations have been identified. Firstly, the sampling method used in the study makes generalization of the results difficult. As the participants were nursing students who met specific criteria, those willing to use the ECG-KAT, ECG-SAT and ECG-SES to assess nurses' or other professionals' competence should conduct a validation study before doing so. Secondly, due to organizational constraints, the test-retest reliability of the tools was only assessed in the piloted version of the 3-instrument toolkit. This makes it difficult to discard between-subject differences as potential cause of the variability found in correlations. To provide more clarity in this matter, future studies should apply test-retest measures to the main sample and then calculate the intraclass correlation coefficient. Thirdly, in regard to the validity of the ECG-SES it is important to highlight that due to the subjective nature of the participants responses, the known-group analysis results could have been influenced by social desirability response bias.[38] Finally, as the ECG-KAT, ECG-SAT and ECG-SES were developed and tested in Spanish, those willing to use them in different languages will have to conduct an appropriate translation and validation process.

Conclusions

The toolkit developed for the assessment of competence in ECG rhythm recognition has shown excellent psychometric properties following a rigorous testing process. The ECG-KAT, ECG-SAT and ECG-SES comprise a valid, reliable and concise yet comprehensive toolkit, which may allow educators to holistically assess nursing students' competence in ECG rhythm recognition. Moreover, its easy and quick applicability could foster the design, implementation and assessment of new educational interventions, which aiming at improving competence in ECG rhythm recognition amongst nursing students, may positively influence patients' outcomes. It is suggested that further studies evaluate the psychometric properties of this toolkit after being translated into other languages and validate its applicability on randomised samples of nurses and nursing students with different professional and educational backgrounds.

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Conflict of interest

Authors declare that there is not conflict of interest.

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Table 1.
Demographic characteristics of the main sample (*N*=293) and the three known-groups.

Characteristic	Main Sample (*N*=293)	Not trained (*n*=98)	Trained immediately before assessment (*n*=91)	Trained 1-3 months before assessment (*n*=104)	Results and significance of the one-way ANOVA comparisons between known-groups
	M ± S.D.	*M* ± S.D.	*M* ± S.D.	*M* ± S.D.	
Age (years)	21.19 ± 5.24	20.12 ± 5.88	21.08 ± 4.66	22.29 ± 4.9	F(2,290) = 4.436, p = .053
	n (%)	n (%)	n (%)	n (%)	
Gender					
Female	236 (80.5)	78 (79.6)	73 (80.2)	85 (81.7)	F(2,290) = 0.077, p = .926
Male	57 (19.5)	20 (20.4)	18 (19.8)	19 (18.3)	
Education Level (completed)					
Upper Secondary Education	225 (76.8)	77 (78.6)	69 (75.8)	79 (76)	F(2,290) = 0.008, p = .992
Degree	68 (23.2)	21 (21.4)	22 (24.2)	25 (24)	
Cooperated in the interpretation of an ECG	114 (38.9)	34 (34.7)	33 (36.3)	47 (45.2)	F(2,290) = 1.363, p = .258

Table 2.
Psychometric statistics of item analysis for reliability and I-CVI of the ECG-KAT (*N*=293).

		Corrected ITC[†]	Cronbach's Alpha if item deleted	I-CVI[‡]
Question 1	Properties of the myocardial cells	.640	.882	1
Question 2	Cardiac conduction pathway	.447	.888	1
Question 3	Function of anatomical structures	.537	.885	1
Question 4	ECG paper grid	.376	.889	.94
Question 5	Defining characteristics of 'p waves'	.485	.887	1
Question 6	Defining characteristics of 'QRS complex'	.615	.883	1
Question 7	Defining characteristics of 't wave'	.512	.886	1
Question 8	Defining characteristics of 'PR interval'	.560	.884	1
Question 9	Defining characteristics of 'QT interval'	.563	.884	.94
Question 10	Clinical relevance of 'ST segment'	.478	.887	.94
Question 11	Duration of the 'QRS complex'	.571	.884	1
Question 12	Duration of the 'PR interval'	.385	.891	1
Question 13	Characteristics of first degree AV block	.621	.882	.94
Question 14	Characteristics of second degree AV block	.560	.884	.81
Question 15	Characteristics of third degree heart block	.511	.886	.81
Question 16	Characteristics of cardiac arrest arrhythmias	.376	.890	1
Question 17	Tachyarrhythmias	.520	.885	1
Question 18	Bradyarrhythmias	.659	.881	1
Question 19	Written interpretation of sinus rhythm	.455	.887	.75
Question 20	The six-stage method	.383	.891	.75

[†] ITC=Item-total correlation
[‡] I-CVI=Item Content Validity Index

Table 3.
Psychometric statistics of item analysis for reliability and I-CVI of the ECG-SAT (*N*=293).

		Corrected ITC[†]	Cronbach's Alpha if item deleted	I-CVI[‡]
1.	Sinus Bradicardia	.379	.934	.81
2.	Torsade de pointes	.881	.916	1
3.	Atrial Fibrillation	.523	.930	1
4.	Ventricular Fibrillation	.771	.922	1
5.	First degree AV-Block	.803	.920	1
6.	Junctional Rhythm	.874	.916	1
7.	Asystole	.744	.923	1
8.	Ventricular Tachycardia (broad)	.740	.923	1
9.	Sinus Rhythm with ST elevation	.798	.920	.94
10.	Second degree AV-Block (Mobitz II)	.773	.922	1

[†] ITC=Item-total correlation
[‡] I-CVI=Item Content Validity Index

Table 4.
Psychometric statistics of item analysis for reliability and I-CVI of the ECG-SES (*N*=293).

		Corrected ITC†	Cronbach's Alpha if item deleted	I-CVI‡
When interpreting an ECG, I am confident I can always…				
1.	Calculate the heart rate manually using a rhythm strip	.805	.974	1
2.	Determine whether the cardiac rhythm is regular or irregular	.772	.975	1
3.	Assess whether there is atrial electrical activity or not	.836	.974	1
4.	Assess whether there is ventricular electrical activity or not	.861	.973	1
5.	Identify whether the cardiac rhythm is originated in the atria or the ventricles	.877	.973	1
6.	Assess the relationship between the atrial and the ventricular activity	.882	.973	1
7.	Measure the interval that determines the atrioventricular activity	.856	.973	1
8.	Identify abnormalities in the duration of the intervals defining the atrioventricular activity	.823	.974	1
9.	Recognise a sinus rhythm	.821	.974	1
10.	Recognise and name any bradyarrhythmia regardless of its characteristics	.848	.974	1
11.	Recognise and name any tachyarrhythmia regardless of its characteristics	.846	.974	1
12.	Recognise and name any heart block regardless of its characteristics	.864	.973	1
13.	Recognise and name any arrhythmia that causes cardiac arrest regardless of its characteristics	.863	.973	1
14.	Recognise and name any life-threatening arrhythmia regardless of its characteristics	.876	.973	1
15.	Recognise and suspect possible signs of ischemia, injury or infarction	.796	.974	.94

† ITC=Item-total correlation
‡ I-CVI=Item Content Validity Index

Table 5.
Factor loadings and total variance explained from the rotated factor structure of the ECG-KAT (*N*=293).

Item by Factor	Factor			
	1	2	3	4
1) Anatomophysiological principles of the cardiac function				
Properties of the myocardial cells	.70			
Cardiac conduction pathway	.54			
Function of anatomical structures	.51			
2) Fundamental concepts of ECG rhythm recognition				
ECG paper grid		.50		
Defining characteristics of ‘p waves’		.61		
Defining characteristics of ‘QRS complex’		.58		
Defining characteristics of ‘t wave’		.58		
Defining characteristics of ‘PR interval’		.53		
Defining characteristics of ‘QT interval’		.60		
Clinical relevance of ‘ST segment’		.51		
3) Interpretation procedure of ECG rhythms				
The six-stage method			.51	
Duration of the ‘QRS complex’			.56	
Duration of the ‘PR interval’			.53	
4) Cardiac arrhythmias’ characteristics				
Characteristics of first degree AV block				.72
Characteristics of second degree AV block				.71
Characteristics of third degree heart block				.69
Characteristics of cardiac arrest arrhythmias				.80
Tachyarrhythmias				.59
Bradyarrhythmias				.68
Written interpretation of sinus rhythm				.55
% of variance	5.47	7.50	5.22	33.25
Cumulative % of variance	5.47	12.97	18.19	51.44

Table 6.
Known groups analysis and Tukey's HSD post-hoc test for multiple comparisons.

Known-Groups	**Not trained** (n=98)	**Trained immediately before testing** (n=91)	**Trained between 1-3 months before testing** (n=104)
Instrument	***M* ± *SD***	***M* ± *SD***	***M* ± *SD***
Known-group comparison	significance	significance	significance
ECG-KAT	***31.43 ± 10.77***	***80.38 ± 21.32***	***53.08 ± 19.34***
Not trained	-	.001	.001
Trained immediately before testing	.001	-	.001
Trained between 1-3 months before testing	.001	.001	-
ECG-SAT	***13.98 ± 12.82***	***73.37 ± 23.67***	***33.63 ± 20.57***
Not trained	-	.001	.001
Trained immediately before testing	.001	-	.001
Trained between 1-3 months before testing	.001	.001	-
ECG-SES	***29.03 ± 14.68***	***75.15 ± 13.71***	***48.71 ± 22.17***
Not trained	-	.001	.001
Trained immediately before testing	.001	-	.001
Trained between 1-3 months before testing	.001	.001	-